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Mechanical Couplings for Joining Polyethylene Pipe TN-45/2012

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Foreword

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The purpose of this technical report is to provide important information available to PPI on a particular aspect of polyethylene pipe butt fusion to engineers, users, contractors, code officials, and other interested parties. More detailed information on its purpose and use is provided in the document itself.

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The Plastics Pipe Institute, Inc.
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MECHANICAL COUPLINGS FOR JOINING POLYETHYLENE PIPE

1.0 Introduction

The use of polyethylene piping material has steadily increased over the past half century and today it's the material of choice for natural gas piping systems up to 12" size. Mechanical couplings and fittings played a vital part in this evolution, especially in the earlier years, when distribution service line installations were the most common application. Many of these mechanical fittings were metallic and connected to steel or cast iron main piping with a PE outlet connection for the service line. Both plastic and metallic mechanical fittings have provided the industry with fast and easy pipe joining, and repair and transition techniques. Their nearly 50 years of performance history is testimonial to the safe and reliable service these fittings provide.

This document will provide a historical time line to assist material engineers, when assessing older PE systems, and to determine what the governing requirements were for mechanical fittings at the time of their installations. It will also review the specified regulatory requirements for mechanical pipe joints, both in general terms and how they should be interpreted for mechanical joints for PE piping.

An outline of recommended mechanical fitting performance capabilities will be provided to assist material engineers in product selection. It includes any ASTM Test Methods or Standard Specifications available to provide guidance in how to evaluate the performance capability of mechanical fittings.

Some of the most common types of mechanical fittings will generically be described. Some mechanical fitting designs are proprietary to a specific manufacturer. Use recommendations and compliance to regulations should be reviewed with the fitting manufacturer prior to installation. Mechanical fittings do not require highly skilled laborers and typically do not require special equipment to be installed. With each design, it is essential that the manufacturer's installation instructions are followed to obtain optimum performance.

2.0 Definition/Designs

There are primarily five different mechanical coupling designs or technologies for joining PE currently in use in North America. All require the use of an internal stiffener when used with PE pipe to prevent long-term creep of the pipe away from the compression forces. These designs can be classified by the method used for completion. These are:

- Tightening of bolts and nuts
- Tightening of compression nut (also referred to as "nut follower").
- Stab or insertion style
- Hydraulic pressure
- Use of an external compression or "completion" ring

Tightening of Bolts

This design is characterized by the use of multiple bolts and nuts being tightened to grip and seal on the polyethylene (figures 1a, 1b). These types of mechanical couplings can also be used to join polyethylene to steel or cast iron gas piping, or ductile iron water piping.

The tightening of the bolts brings together internal gripping rings and a sealing element. As the bolts are tightened, the outer ring, commonly called the retaining ring, forces the gripping mechanism or ring and sealing gasket into a state of compression onto the polyethylene, thus creating restraint and a gas tight seal. The tightening of nuts and bolts is to a specified torque value prescribed by the manufacturer’s installation instructions.

Figure 1a – Steel body, bolt together coupling

Figure 1b – Plastic body, bolt together coupling

Tightening of Compression Nut *(Nut Follower)*

With this design, the operator is required to tighten a nut to a stop or prescribed torque value. As with the “bolt” design fitting, as the operator tightens the nut down, the internal gripping ring and sealing gasket are brought down onto the polyethylene pipe to restrain and seal. In some designs, there is a prescribed torque value, however in others; the operator is required to tighten the fitting to a stop point located on the coupling body. The gas seal and restraint (grip) are dependent upon the amount of tightness the operator applies to the compression nut. Examples of compression nut style couplings are depicted in figures 2a and 2b below.

Figure 2a – Cast body compression coupling

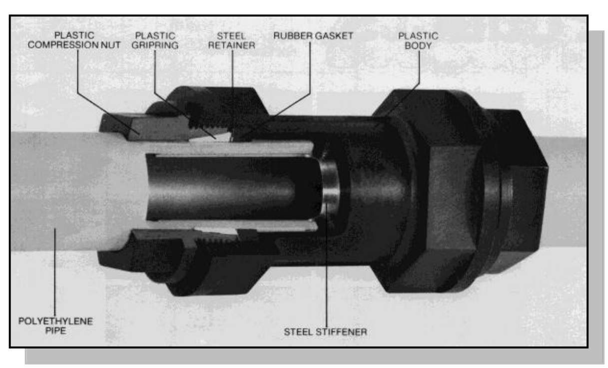

Figure 2b – Nylon body compression coupling

Stab or Insertion

The “stab” or insertion style coupling requires no tightening of bolts or compression nut. With the stab type, the seal and restraint are accomplished through independent components. The coupling contains either single or multiple rubber orings that provide a seal on the outside diameter, inside diameter or both diameters of the polyethylene tubing which has been inserted into the fitting. In the case of an outside diameter seal fitting, the inside diameter of oring is smaller than that of the outside diameter of the polyethylene tubing, thus compressing the rubber oring onto the PE tubing surface and coupling body surface creating a gas tight seal. Likewise, for the inside diameter sealing coupling version, the sealing oring would have a larger diameter than the inside diameter of the tubing, again, compressing the tubing wall to the oring creating a gas seal.

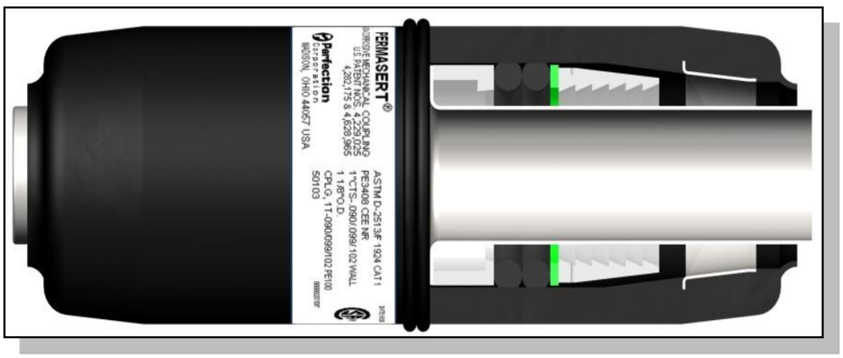

Figure 3 – Polyethylene stab type coupling

Hydraulic Pressure

This type of joining method is no longer commonly used on polyethylene, however because there may exist product in the operator’s system we review the technology here. This type of coupling involves a steel body product with two hydraulic port holes. Internally, there are gripping plates and seals that are forced onto the piping via hydraulic fluid pressure. Use of this fitting requires that the operator use and maintain a hydraulic pump. The hydraulic hose is attached to the fitting body and hydraulic fluid is pumped into the fitting body thus forcing the gripper and sealing mechanisms onto the pipe. Fluid pressure is measured on a pressure gauge attached to the pump. Installation pressure is predetermined by the manufacturer and detailed in the installation instructions.

Figure 4 – Hydraulic style coupling

External Compression Ring

For the mechanical coupling using an external compression or "completion" ring, the operator inserts the polyethylene over an insert stiffener. The insert stiffener may or may not be integral to the fitting body and can be smooth or serrated. Prior to this step, the operator slides the compression ring over the outside of the polyethylene tubing. After the polyethylene has been inserted, the compression ring is brought over the coupling body and/or polyethylene. This interference fit creates a compressive force between the polyethylene and the insert stiffener. The assembly typically requires the use of a special tool to bring the compression ring onto the fitting body. This design may or may not contain an elastomeric sealing element, in some designs the compression of the PE onto the griping element and/or internal stiffener also creates the seal. Assembly is complete when the compression ring has been brought into contact with a stop on the coupling.

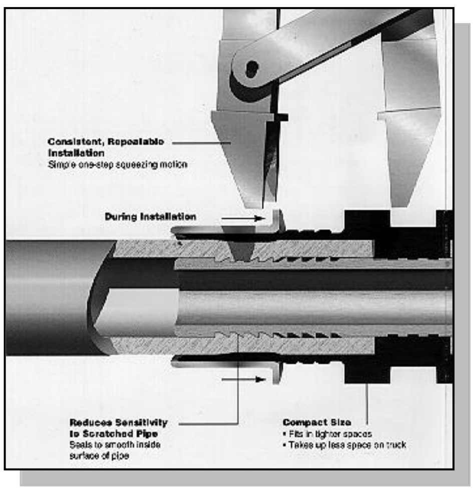

Figure 5 – External Compression Ring style coupling

3.0 Compression Couplings Background

When plastic pipe was first designed and developed for the natural gas distribution industry in the 1960's, the dimensions were called IPS and CTS or Iron Pipe Size and Copper Tubing Size. The outside diameter (OD) of IPS pipe was based on the corresponding iron pipe outside diameter so that the same fittings that were used for metal pipe could also be used for plastic pipe. For example, nominal 2" IPS PE pipe has an outside diameter of 2.375", which is the OD of metal pipe.

When mechanical compression couplings were first used for plastic gas pipe in the early 1960's they provided a leak-tight seal only, and this seal was based on the OD dimensions. These first compression couplings, which were originally designed for metal pipe, provided the necessary gas-tight seal, but did not provide resistance (restraint) to pull out. As the use of plastic pipe and particularly PE pipe, increased, the compression coupling manufacturers began to design their couplings specifically for plastic pipe. In the case of PE pipe, this included an insert stiffener to provide the needed rigidity to the PE to improve the required seal. By the late 1960's, some compression coupling manufacturers also began to design their fittings with pullout resistance in addition to leak-tight seals. By 1980, there were several manufacturers that sold compression couplings that provided both a leak-tight seal and gripping mechanisms that provided pullout restraint.

In their 1972 report, "Comparison of Long-Term Sealing Characteristics of Compression Type Couplings on Steel & Polyethylene Pipe" Dresser Manufacturing stated, "A new mechanical design was initiated to develop a mechanical joint for PE. Requirements were obviously long-term reliable sealing ability and a joint locking strength equal to the longitudinal strength of the plastic pipe being joined, as required by (our interpretation) the DOT regulations Volume 35, number 61, paragraph 192.273 (a)". This statement indicates that Dresser Manufacturing interpreted the code as meaning that a compression coupling needed to have restraint to pullout and they were manufacturing couplings to meet that requirement. The mechanical couplings manufactured by Dresser in sizes 2" IPS and below had a locking feature to prevent pullout. This had been the industry standard since the late 1960's.

In the late 1970's as a result of two compression fitting pullout failures in Fremont, Nebraska and Lawrence, Kansas, the DuPont Company published an article, "Pull Out Forces on Joints in PE (Polyethylene) Pipe Systems", in which the joint strength for compression fittings ½" to 1" was deemed "equal or greater" than pipe strength. DuPont deemed compression fittings larger than 1" to have joint strength "less" than pipe strength.

As a result of several more industry gas pipeline failures due to PE pipe pulling out of a non-restraint compression coupling, some manufacturers now include caution statements in their literature, such as, "When pipe pullout could occur as a result of forces other than that caused by internal line pressure of 150 psig maximum, pipe joint MUST be anchored. Failure to anchor pipe joint could result in escaping line content and cause property damage, serious injury or death".

4.0 Industry Codes/Standards for Mechanical Couplings

I. DOT Part 192

The key section dealing with compression couplings in the original DOT Part 192 was Part 192.273, which required that "the pipeline must be designed and installed so that each joint will sustain the longitudinal pullout or thrust forces caused by contraction or expansion of the piping or by anticipated external or internal loading." Other sections of Part 192 that affect compression coupling design and installation are 192.143, 192.161, and 192.321. Also, DOT Part 192.703 requires that each segment of pipeline that becomes unsafe must be replaced.

In 1980, after the Fremont, Nebraska and Lawrence, Kansas compression coupling pullout incidents, Part 192 was revised to incorporate additional mechanical joint requirements in Part 192.283. These new requirements included procedures for qualifying joining procedures for mechanical joints and qualifying person to make such joints, including a pullout test that requires the pipe to neck down with at least 25% elongation to qualify the joining procedure.

II. AGA Plastic Pipe Manual

The industry document that the gas companies rely on the most for general guidelines on installing plastic pipe is the AGA Plastic Pipe Manual. This manual is prepared by plastics piping experts in the AGA Plastic Materials Committee, both gas companies and manufacturers, to assist the users with proper installation and maintenance of plastic pipe. The original 1977 AGA Manual references DOT Part 192.273 and states, "The installed joint must effectively 'sustain longitudinal pullout or thrust forces caused by contraction or expansion of the piping or by anticipated external or internal loading.' Such provision may be made in the design of the joint or in the installation or a combination of both".

The 1977 AGA Manual also states, "Earth movement, ground movement and third party construction activity can impose stresses on the pipe which can be transmitted to joints. In most situations it is desirable to have pipe joints which are as strong as the pipe itself in the axial (longitudinal) direction. Mechanical joints not specifically designed for use with plastic pipe may not provide complete resistance to pullout."

Later versions of the AGA Plastic Pipe Manual were updated to reflect the new mechanical joint requirements in DOT Part 192.283.

III. ASTM F17

The industry standard that the gas companies rely on the most for product requirements when installing plastic pipe is ASTM D 2513. This is a consensus standard prepared by plastics piping experts in ASTM F17, both gas companies and manufacturers, that is referenced by DOT in Part 192. Early versions of ASTM D 2513 stated, "Mechanical joints categorized by 8.14 should be engineered to provide adequate resistance to pullout caused by thermal contraction and earth movement, or both, anticipated during its service life".

D 2513 also stated, "Earth settlement, internal pressure and ground movement can impose stresses on the pipe which when in the vicinity of joints can be transmitted to the joints themselves. It is desirable to have pipe joints that are as strong as the pipe itself in the longitudinal (axial) direction. For those mechanical joints made with fittings which are not designed to restrain the pipe against pullout forces which could be experienced, provisions must be made in the field to prevent pullout. Another somewhat limited alternative is to use long sleeve-type fittings which permit limited movement without loss of the pressure seal. Otherwise, provisions must be made in the field to prevent pullout through suitable anchoring at the joint".

In 1980, while DOT Part 192 was being revised to incorporate additional mechanical coupling requirements in Part 192.283, ASTM D 2513 was also revised. Mechanical fitting categories were established based on the fitting leak-tightness and the fitting pullout resistance.

- A category 1 fitting provides both a seal and full pullout restraint.
- A category 2 fitting provides a seal only.
- A category 3 fitting provides seal and limited restraint, equivalent to the anticipated thermal stresses occurring in a pipeline.

Note 9 was also revised to state, “The ability to restrain pipe or tubing to its yield as specified above does not guarantee that a properly installed joint will prevent pullout under actual long-term field conditions. Joints that cannot pass this test would be expected to pullout under actual long-term field conditions. To date, this test is the best available for disqualifying unsound joints”.

In more recent years, standards for mechanical fitting design and performance have been written specifically for natural gas distribution systems that contain performance requirements intended to establish minimum requirements for longitudinal force capability and to verify pullout resistance. Separate standards now exist for both plastic and metal bodied compression fittings that impose the same level of pullout resistance regardless of the compression design type. ASTM F1948 - Standard Specification for Metallic Mechanical Fittings for Use on Outside Diameter Controlled Thermoplastic Gas Distribution Pipe and Tubing and ASTM F1924 - Standard Specification for Plastic Mechanical Fittings for Use on Outside Diameter Controlled Polyethylene Gas Distribution Pipe and Tubing require full resistance to pullout forces equal to that which would cause permanent deformation of the PE pipe. Additional requirements for long-term pullout resistance include a “dead weight” or constant tensile load joint test that subjects the joint to an internal pressure and longitudinal force to achieve a defined stress in the PE pipe.

IV. National Transportation Safety Board (NTSB) Recommendations

In 1985, NTSB reported that it had determined that the probable cause of a mechanical joint failure was the gas company’s failure to understand the limitations of the coupling, which led to the pullout of the PE pipe from the coupling. This NTSB Report prompted AGA to issue a memo to all its member companies regarding NTSB Recommendation P-85-30. In this memo, AGA stated, “When using couplings to join plastic pipe, we urge you to consider the forces anticipated to act on the coupling and assure that these forces will not exceed the capabilities of the coupling”. This NTSB Report also led to DOT Advisory Bulletin in 1986 (ADB-86-02) on mechanical couplings. This advisory bulletin was intended to inform natural gas pipeline operators to review procedures for using mechanical couplings, and to ensure that coupling design, procedures, and personnel qualifications meet Part 192.

Most recently, on March 4, 2008, as a result of more compression coupling pullout failures, PHMSA issued Advisory Bulletin ADB-08-02 on mechanical couplings. This ADB states, "PHMSA advises operators of gas distribution pipelines using mechanical couplings to do the following to ensure compliance with 49 CFR Part 192: (1) Review procedures for using mechanical couplings, including the coupling design and installation and ensure that they meet manufacturer's recommendations. PHMSA also advises operators of gas distribution pipelines using mechanical couplings to consider taking the following measures to reduce the risk of failures of mechanical couplings:

(4) Use Category 1 fittings only if mechanical couplings are used on pipe sizes ½" CTS to 2" IPS.
(6) Consider whether to adopt a full replacement program if there are too many unknowns related to couplings in service."

5.0 Conclusion

Although there have been some incidents of joint failures in the long history of the use of mechanical compression fittings installed on PE pipe, the overall performance record of these mechanical joints has been excellent. Most accidents can be attributed to misuse or misunderstanding of the fitting capabilities at the time of installation. Resulting design and performance requirement improvements, along with an increase in the understanding of the application and limitations of different types of compression fittings has served to ensure that modern compression jointing technologies are safe and reliable.

Well defined installation instructions ensure that compression fittings can be easily and quickly installed, and that they are installed consistently and correctly.

With an understanding of the piping system and its anticipated operating conditions a system designer can confidently select the proper fitting design needed to provide trouble-free service.